



THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

**IPC TECHNICAL PAPER SERIES
NUMBER 11**

**HARDWOOD BARK PROPERTIES IMPORTANT TO THE
MANUFACTURE OF FIBER PRODUCTS**

D. W. EINSPAHR AND MARIANNE HARDER

AUGUST, 1975

INTRODUCTION

The need to improve forest utilization has resulted in increased use of harvesting methods that involve chipping small-sized material (branches, tops and undersized trees) prior to debarking. Little is known about the bark properties of most hardwood species. Preliminary investigations indicate that there are major between-species differences in bark characteristics and, because of such variables as species mixtures employed, end product requirements and mill processes and mill capacity, there is "no universal best solution" to handling chips high in bark.

The research described is part of an expanding study aimed at defining the fiber industry's bark problem. Needed are the bark properties of the major pulpwood species so that mill-by-mill decisions can be made on the best solution to specific bark problems.

Described in the paper (presented at the Forest Products Research Society and Southern Forest Experiment Station Symposium on "Utilization of Hardwoods Growing on Southern Pine Sites") are the hardwood bark properties important to the manufacture of fiber products. Illustrated is the type of data being generated for a number of important hardwood pulpwood species.

This paper is being submitted to Forest Products Journal for publication.

HARDWOOD BARK PROPERTIES IMPORTANT TO THE MANUFACTURE OF FIBER PRODUCTS

D. W. Einspahr and Marianne Harder¹

INTRODUCTION

Evidence continues to accumulate supporting earlier predictions of softwood fiber shortages by the year 2000 and hardwood shortages by the year 2010 (1). Predicted wood and fiber shortages have resulted in renewed efforts to increase the available wood fiber supply. One of the most promising approaches is the use of "whole-tree chips." This approach has the advantage of producing immediate increases in per acre yields of approximately 100% for hardwoods and 20-40% for pines and other conifers. Development of most short rotation, high yield, wood production systems also hinges on the use of whole-tree chipping. Whole-tree chipping most often implies chipping in the woods and chipping prior to debarking. The increased yields produced by such a system result from the use of unmerchantable tops, branches and undersized trees. In addition to increased wood and fiber yields, major reductions in harvesting and transportation costs are predicted because of the bulk handling techniques that can be employed from the tree to the mill. Whole-tree harvesting and chipping appears to be here to stay. The problem is how to make the best use of this source of fiber.

Associated with the use of whole-tree chips is a modest decrease in wood fiber quality (the type and amount of quality loss varies with tree species) and numerous problems associated with the so-called "bark problem." Whole-tree chips can be expected to contain 12-18% bark by weight. The chemistry and

¹Senior Research Associate and Research Assistant, Division of Natural Materials & Systems, The Institute of Paper Chemistry, Appleton, Wisconsin. This paper is a summary of information presented at the Forest Products Research Society and Southern Forest Experiment Station Symposium on "Utilization of Hardwoods Growing on Southern Pine Sites," Alexandria, Louisiana, March 10-14, 1973.

morphology of bark varies greatly from tree species to tree species and, as a result, the bark of some species poses virtually no problems while the bark of others can be expected to be a source of numerous difficulties.

There are a number of alternative solutions to the bark problem and they range from removing virtually all the bark to the removal of none of the bark. Most companies have failed to define their problem and have instead taken the "try it and see" approach with whole-tree chips. Their experience in the use of whole-tree chips (bark included) is difficult to evaluate, partly because of the other changes that are taking place at the same time (use of new wood species, recycling of water, etc.) whole-tree chips are introduced into mill operations. The most common complaints, in addition to increased dirt in the final product, include: excessive equipment wear (valves, refiners, screens, etc.), decreased pulp yield, increased chemical costs, frequent digester plugging, and increased evaporator scaling. Our preliminary studies indicate that there may be additional subtle changes in sheet properties (drainage, strength, etc.) associated with the use of bark that will influence machine speed. The complaints experienced to date suggest that to use whole-tree chips without bark removal will require increased digester capacity, improved chip washing and pulp washing procedures, increased cleaner capacity, and increased recovery furnace capacity.

PHILOSOPHY OF PROGRAM

Experience gained in early industry-sponsored studies on wood/bark adhesion and methods of segregating bark and wood chip mixtures resulted in the philosophy that there was no "universal" solution to the bark problem. Between-species differences in bark characteristics are large. Because of mill-by-mill differences in: (1) the mixture of species employed, (2) end-product requirements, (3) existing

investments in harvesting and debarking equipment, and (4) digester, cleaner and recovery furnace capacity, a single best solution to the problem does not appear possible.

Consistent with the no "universal solution" philosophy, the approach adopted was to provide the companies with the basic bark characteristics of the major pulpwood species, thus enabling them to put together the best solution to their specific problem. We believe that proper definition of the problem is the first step toward solving it.

INFORMATION REQUIRED

Taking into consideration the several currently available methods for upgrading "whole-tree chips," which range from flotation procedures and compression debarking to pulping the debarked chips, the information given in Table I was considered important in defining the problem. The procedure followed has been to first review the literature and summarize existing data. Next, pulpwood-sized trees were sampled (2-6 trees) and the required measurements made to complete the characterization.

The reasons for measuring the bark properties listed in Table I are, for the most part, self evident. In many instances wood properties were also measured because the success of a number of segregation procedures hinges on there being differences between the bark and wood. Considerable emphasis has been placed on the consequences of pulping the bark. Knowledge of bark morphology, specific gravity, extractives, fibrous yield, and ash content are important in assessing the possibilities of this approach. Ash content is reported to be related to recent increases in recovery furnace scaling problems and has recently been added to the list of determinations considered to be important.

SPECIES TO BE INVESTIGATED

This paper is a progress report rather than a completed study. Characterization investigations are nearing completion on 16 pulpwood species and included are quaking aspen, sugar maple, white birch, northern red oak, sweet gum, southern red oak, white oak, silver maple, loblolly pine, slash pine, Douglas-fir, western hemlock, white spruce, jack pine, balsam fir and eastern cottonwood. Sixteen additional species including eight hardwoods (Table II) are to be measured in the next 16-month period.

TYPE OF DATA GENERATED

The type of data being generated by the program is illustrated by the information presented in Tables III-VI. Presented is information on quaking aspen, sugar maple, white birch, northern red oak, southern red oak and white oak. Table III presents information on specific gravity (oven dry wt./green volume), alcohol-benzene extractives and density at 100% moisture content (green weight/green volume). The density at 100% moisture content is the density near that of green chips. Values greater than one indicate the material will sink in water and values less than one indicate the material will float. High levels of extractives are associated with pitch problems on the paper machine.

Table IV compares the wood/bark adhesion of a number of hardwood species. The bark adhesion measurements are determined on small specially prepared tabs that confine the failure to the cambium zone. The measurements determine shear parallel to the grain and are made on an Instron tester. Wood/bark adhesion values are believed to be one of the factors influencing mechanical debarking and wood/bark separation that occurs as a result of chipper action.

Summarized in Table V are bark strength measurements. Toughness, an Instron tester measurement, determines the energy required to rupture a small bark or wood sample by a bending force parallel to the diameter of the tree. Bark strength measurements are made using essentially the same procedure used in determining wood/bark adhesion. The values reflect shear parallel to the grain. Bark strength values are expected to reflect the reaction of bark to mechanical treatment. The simulated hammermilling test was run to further evaluate the reaction of wood and bark to mechanical treatment. The test involved the use of a modified "Micro Pulverizer"* and the reduction in particle size of bark and wood samples run separately was used to evaluate the potential of the procedure for upgrading whole-tree chip mixtures. Too little information is presently available to properly evaluate the relationships between the bark strength measurements made and the overall usefulness of the information. Preliminary information suggests that there is a correlation between dormant season wood/bark adhesion and the strength of the inner bark.

Table VI provides an insight into the usable fiber in bark. The bark was pulped using a kraft cooking procedure that for hardwoods normally results in about 50% yield and a Kappa number of 8-12 [Thode, et al., (2)]. After pulping, the fibrous material was screened and the usable bark fiber is the fiberlike material retained on the 60 and 100-mesh screens. Figure 1 illustrates the type of fibrous material obtained from the bark of quaking aspen and northern red oak. Sclereids reported are thick-walled sclerenchyma type cells that very often are found in clumps (Fig. 1). When undercooked (high yield pulps), the clumps do not separate and can cause "fish-eyes" in calendered papers and pin holes in

*Pulverizing Machinery Company, Roselle Park, N. J.

coatings. Increased equipment wear and greater pulp cleaning capacity (Centri-Cleaners, etc.) is anticipated when species like white birch and aspen chips containing large amounts of bark are pulped.

CONCLUSIONS

Large differences exist between hardwood species in morphology, wood chemistry and mechanical properties of the bark. Preliminary observations indicate that there are several trends that seem to hold for the hardwood species investigated. Average growing season wood/bark adhesion is similar for all species ($3-6 \text{ kg/cm}^2$) and observations made on the zone of failure demonstrate failure quite consistently occurred in the cambium zone or the newly formed xylem elements just inside the cambium. Dormant season wood/bark adhesion is higher than during the growing season and failure usually occurs in the inner bark relatively close to the cambium zone. Extremely high dormant season adhesion appears to be associated with the presence of large numbers of fibers in the inner bark.

Preliminary observations of dormant season separation of bark from wood during chipping suggests separation appears to be influenced by bark thickness and wood density. Greater chipper knife impact and satisfactory separation occurs near the cambium zone-inner bark region on thick-barked species of high wood density. The presence of fiber in the inner bark is expected to reduce the effectiveness of the chipper action. Observations made upon the fiberlike structures and sclereid clumps which survive the pulping indicate that with experience the relative levels of these elements can be predicted from bark morphology. The most difficult to predict will be the degree to which the sclereid clumps separate. As clumps, sclereids have been shown to cause paper-making problems. As separate entities they are expected to cause little or no difficulty.

As more and more bark information becomes available, interrelationships between bark morphology, bark strength and fibrous yield become evident. With bark characterization information in hand, such solutions as screening, pulping, air flotation, water flotation, hammermilling and/or compression debarking can be given appropriate consideration as ways of handling the bark problem in whole-tree chips.

ACKNOWLEDGMENT

The authors of this paper are indebted to the pulp and paper companies who supported the work and supplied samples. They also wish to acknowledge John Hankey for his photomicrographs and characterization of bark pulp and Roger Van Eperen, John Peckham and his staff for adhesion, strength and toughness measurements and the pulping work that was carried out. Thanks also go to the staff within the Division of Natural Materials & Systems for their assistance with collections and certain aspects of the characterization work.

LITERATURE CITED

1. U.S.D.A., Forest Service. The outlook for timber in the United States. U.S.D.A., Forest Service Forest Resource Report No. 20, October, 1973. 367 p.
2. Thode, E. F., Peckham, J. R., and Daleski, E. J. An evaluation of certain laboratory pulping methods. Tappi 44(2):81-8(1961).



Figure 1. Illustrated Above are Photomicrographs of Pulped Bark Samples of Quaking Aspen (Top) and Northern Red Oak (Bottom). Both are Photomicrographs of Bark Components that were Retained on a 60-Mesh Screen. The Quaking Aspen Sample Contained an Estimated 80-90% Phloem Fibers with Very Small Amounts (5-10%) of Sclereids. The Northern Red Oak Sample also Contained Primarily Phloem Fibers (90-95%) with Very Small Amounts of Sclereids (<5%). Magnification - 35X

TABLE I

BARK INFORMATION REQUIRED FOR EACH SPECIES

Inner and Outer Bark Morphology
Specific Gravity
Extractives
Fibrous Yield
Wood/Bark Adhesion
Bark Strength
Bark Toughness
Reaction to Hammermilling
Water Flotation Behavior
Fuel Value*
Ash Content*

*Not part of earlier investigations but
added recently because of energy costs
and emphasis on pulping bark.

TABLE II

ADDITIONAL SPECIES TO BE INVESTIGATED

SHAGBARK HICKORY	LONGLEAF PINE
BEECH	SHORTLEAF PINE
WHITE ASH	ENGELMANN SPRUCE
TUPELO GUM	LODGEPOLE PINE
YELLOW POPLAR	PONDEROSA PINE
WESTERN COTTONWOOD	WESTERN LARCH
RED ALDER	REDWOOD
SYCAMORE	RED PINE
VIRGINIA PINE	BLACK SPRUCE

TABLE III

WOOD AND BARK CHARACTERISTICS OF PULPWOOD SPECIES

Characteristic	Quaking Aspen	Sugar Maple	White Birch	Northern Red Oak	Southern Red Oak	Northern White Oak	Southern White Oak
Specific Gravity (ovendry wt./green volume)							
Wood	0.38	0.59	0.49	0.56	0.60	0.62	0.68
Whole bark	0.50	0.54	0.56	0.65	0.73	0.53	0.56
Inner bark	0.40	0.69	0.57	0.53	0.72	0.60	0.69
Outer bark	0.55	0.49	0.54	0.71	0.74	0.47	0.47
Extractives, %							
Wood	3	1	4	4	5	2	5
Bark	15	6	17	11	5	6	6
Density at 100% moisture ^a (green wt./green volume)							
Wood	0.79	1.24	1.01	1.06	1.26	1.30	1.38
Bark	1.15	1.08	1.16	1.18	1.39	1.05	1.13

^aValues greater than 1 indicate the material will sink while at values less than 1, the material will float.

TABLE IV
BETWEEN SPECIES COMPARISONS OF WOOD/BARK ADHESION

Species	Wood/Bark Adhesion, kg/cm ²	
	Peeling Season	Dormant Season
Shagbark hickory	5.3	26.9
Eastern cottonwood	4.4	13.2
Quaking aspen	6.4	11.4
Bur oak	5.8	9.6
White birch	5.1	12.0
Sugar maple	5.8	10.1
Northern red oak	2.5	8.4
Southern red oak	5.4	14.0
Southern white oak	-- ^a	7.2
Northern white oak	4.8	7.8

^aPeeling season adhesion not sampled but assumed to be similar to southern red and northern white oak.

TABLE V

BARK STRENGTH CHARACTERISTICS OF HARDWOOD SPECIES

Characteristic	Quaking Aspen	Sugar Maple	White Birch	Northern Red Oak	Southern Red Oak	Northern White Oak	Southern White Oak
Bark Strength, kg/cm ²							
Inner bark	9.0	1.4	1.6	2.1	3.6	4.6	4.7 ^a
Outer bark	4.9	4.7	9.8	4.6	3.4	3.2	
Toughness							
Inner bark	0.22	0.25	0.10	0.13	0.11	0.16	0.12
Outer bark	0.10	0.10	0.10	0.18	0.14	0.10	0.09
Sapwood	0.45	1.20	0.68	0.93	0.55	0.62	0.98
Hammermilling, %							
Bark removed	34	29	38	34	46	37	38
Wood loss	5	5	6	10	6	5	3

^aBark strength value for total (inner + outer) bark.

TABLE VI

PULP AND FIBER YIELD FROM BARK

Characteristic	Quaking Aspen	Sugar Maple	White Birch	Northern Red Oak	Southern Red Oak	Northern White Oak	Southern White Oak
Pulp yield, % (bark)	34	34	36	28	31	35	37
Usable bark fiber, % ^a	10	3	0	5	4	3	3
Sclereids remaining, % ^a	1	0.2	0.7	0.2	0.1	0.2	0.1

^aUsable bark fiber and sclereids remaining are the fibers and sclereids retained on the 60- and 100-mesh screens. The percentage given is the yield based on whole bark samples. The major proportion of fibers and sclereids for all species was located in the inner bark.